The Impact of Corrosion on Fire Department Vehicle Fleets

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CERTIFICATION STATEMENT

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Abstract

The problem this research project addressed was the increasing cost of corrosion related repairs to Bath Fire Department vehicles. There had been a sharp increase in corrosion repairs since 2010. In 2016, the fire department had to replace a 2005 Pierce pumper due to excessive corrosion and structural compromise of the frame. This required keeping another pumper that was due for replacement beyond its expected service life.

The purpose of the study was to determine what the possible causes were for the increase in corrosion issues and what steps the department could take to reduce these issues in its vehicle fleet. The study also looked at what other departments were experiencing and what steps they were taking to prevent corrosion issues.

Review of pertinent literature revealed little information specific to fire service vehicles. There were many good sources of information in the transportation, highway maintenance, and military fields. Local vehicle repair shops also provided good sources of information.

Descriptive research was the methodology chosen for this paper. Data was collected from area highway maintenance departments to determine if products were applied to area roadways that could contribute to accelerated corrosion. A survey was developed and sent to fire departments in northeast Ohio. This survey was also completed by a select number of departments in areas of the country where snow and ice control were not required. Though corrosion damage appears to affect all vehicles equally, the survey only looked at major fire apparatus in order to focus on vehicles with long years of service expectency.

The results of this research showed a definite correlation between the use of snow and ice control products and increased corrosion damage. The most commonly affected areas were body components, electrical systems and braking systems. Though not as frequent, major structural compromise that required premature removal of vehicles from service was reported.
Results of preventive measures were inconclusive in vehicles that had not received regular treatments since they were new. In new vehicles, these preventive measures show significant reduction in corrosion damage.

The recommendations being made as a result of this study are to develop a written corrosion control plan for Bath Fire Department. This plan should encompass vehicle construction methods and materials that reduce corrosion issues. Regular vehicle washing, including underbody structures is recommended. Annual corrosion inspections should be conducted, along with application of a corrosion inhibiting product. Vehicles showing excess levels of corrosion should be evaluated for scale removal and re-painting using a corrosion inhibiting paint. These steps could dramatically reduce the cost of corrosion related repairs over time and possibly extend the useful service life of the vehicle.

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Introduction

Providing fire and emergency medical services is extremely demanding. The effect of this demand is not limited to personnel. Fire department vehicles are subject to significant wear and tear over their service life. Vehicles are operated in all types of weather, carry extreme weight loads, and run for extended periods of time while stationary. Preventive maintenance is a key component of keeping fire vehicles reliable and operating properly.

In 2017, a fire engine with a projected service life of 20 years was removed from service after only 12 years due to extensive corrosion of the main frame rails. The cost of replacing this vehicle was in excess of $450,000. As a result, an older engine that was due for replacement had to be kept in service. The engine that was kept has already had over $10,000 in corrosion related repairs in 2017, with $6000-8000 in additional repairs planned for 2018. Approximately $50,000 had been spent on other vehicles in the fire department fleet for corrosion related repairs since 2014.

The problem this research project addressed was the effect of corrosion on the fire department vehicle fleet and its impact on the fire department budget and vehicle reliability.

Purpose

The purpose of this descriptive research project was to provide research based information regarding factors that are contributing to the corrosion issues in the department's vehicle fleet and what steps could be taken to stop or minimize the development of corrosion.

This descriptive research project is intended to answer the following questions:

1- What factors are contributing to the corrosion issues in the Bath Fire Department (BFD) fleet?
2- What steps can be taken to stop or minimize the development of corrosion?
3- What are other fire departments experiencing in regards to vehicle corrosion?
4- How are other departments addressing corrosion prevention in their vehicles?

Background and Significance

Bath Township is a small community located on the west side of Akron, Ohio. The community covers ten square miles with a population of approximately 10,000 residents. It is a diverse mix of high density commercial, suburban, and rural areas. Over fifty percent of the area has no public water or sewer system, relying instead on private wells and septic systems. There is also significant park land, part of which is the Cuyahoga Valley National Park.

BFD is a combination department that employs 11 full-time and 40 part-time personnel. The department runs approximately 1500 calls for service annually from two fire stations. There are three people on duty at Station One around the clock. Station Two is a shared operation with adjoining Copley Township. Two people staff the station around the clock, one paid by Bath and one by Copley. Station Two is used on a first come, first serve basis between the two communities.

BFD currently has ten vehicles in its fleet. Station One currently houses two ambulances, two engines, one water tender, and a supervisor's vehicle. Station Two has one ambulance that is purchased and maintained by Bath Township. The engine at Station Two is purchased and maintained by Copley Township. The Station Two units are utilized by both communities on a first come-first served basis. The three vehicles remaining are administrative staff vehicles for the chief, assistant chief, and fire inspector. It has been generally accepted practice that fire apparatus (engines and tankers) have a projected service life of 20 years, ambulances six to eight years, and staff vehicles ten years. Appendix A illustrates the amount of runs and mileage per unit annually for the last three years. Staff vehicles were not included in these calculations, as their mileage is not tracked on a daily basis.

In January 2018, a restructuring of operations at Station Two occurred. Though both communities continued to share the facility and its operational costs, staffing and incident responses were completely separated. Each department provided its own staffing and equipment for fire and emergency medical responses. This change had both positive and negative impacts on BFD. One positive effect was the reduced amount of wear and tear on the ambulance that was assigned to Station Two as it would only be used for incidents in one community instead of two. The biggest negative impact was BFD now needed to place an engine at this station for fire responses. Having only two engines to cover two stations made reducing vehicle down time for essential maintenance and repairs to a bare minimum.

BFD has a comprehensive program for preventive maintenance and service testing of all vehicles in its fleet. However, an issue had developed in recent years with excessive damage and required repairs to the vehicle fleet due to corrosion. Items that had been the most affected were brake system components, fuel and air tanks, exhaust systems, and electrical components.

BFD is supported financially by three separate tax levies that generate approximately two point two million dollars per year. Close to 90 percent of this funding goes to personnel and other fixed costs, leaving approximately $230,000.00 per year for discretionary and capital item purchasing. Repairs to the fire department fleet have averaged around $40,000.00 per year since 2014.

BFD is a small department with very little depth in terms of reserve fire vehicles. If a unit suffers a breakdown or structural failure due to corrosion, there is not a replacement at the ready to fulfill its mission. The time required to order and take delivery on a replacement vehicle can, in some instances, take up to 12 months. If the vehicle being replaced is not useable, this would leave the department severely under equipped and require obtaining loaned or rented equipment to fill the void. Finally, the cost of any repairs and replacements could easily overwhelm the department's available financial resources.

A brief phone poll was conducted with several other fire departments in the area around Bath Township. The data collected from the poll shows that corrosion issues are not a problem confined to Bath Township alone. Several departments in the area have had similar issues with their vehicle fleets, and at least one has had to replace a vehicle prematurely due to corrosion damage.

Upon completion of the research on this topic, the writer hoped to have the information required to make recommendations on a comprehensive corrosion prevention plan. The research document will be used to work further with the township administration and department personnel to create a plan that will minimize the financial burden of excessive repairs and premature replacement of fire department vehicles in addition to keeping both the employees and the community as safe and healthy as possible. *The potential impact this study could have on Bath Fire Department is reduced repair expenses, equipment downtime, and premature equipment failure due to corrosion damage.*

Literature Review

Jeff McDiffit and Chris Salwan, representatives of Fallsway Equipment Company in Akron, Ohio report (phone conversation on December 20, 2017) that corrosion related repairs make up 50-60 percent of their annual business. They stated this problem spans all makes and models of fire and emergency medical apparatus currently on the market. They also reported a sharp increase in the amount and severity of corrosion related issues since the inception of using liquid de-icing agents on area roadways during winter weather. The components they stated as most commonly affected are consistent with what has been observed within Bath Fire Department.

Initial review of pertinent literature shows there is very little information available that relates directly to the fire service and fire department vehicles specifically. The commercial trucking and roadway maintenance industries had recognized this issue for some time and had some valuable insights on the issue.

ASM International (2000) identified corrosion as a natural process that moves all materials toward their lowest energy state. Therefore, materials like iron and steel are naturally combining with readily available environmental elements like oxygen and water in order to return to their original state as iron oxides (iron ore.) Corrosion is therefore formally defined as "A chemical or electrochemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties (pg. 2)." The speed and extent of corrosion can vary widely based on the environment the material is subjected to and the elements present in that environment (ASM International, 2000).

In the United States, approximately 70% of the roads are in areas that receive at least 5 inches of snow annually with additional areas affected by seasonal freezing rain (Houska, 2007).

Lockridge (2007), Xi and Xie (2002), and Nazari, Shi, Bergner, Fey (2015) identified the use of chemical de-icing agents on roadways as a primary environmental source of corrosion in motor vehicles. The two agents most commonly cited are calcium chloride and magnesium chloride.

Liquid de-icers have been used in the State of Ohio since early into the new millennium. Such materials cost less than conventional rock salt, and can be put down prior to incoming winter weather events to prevent ice and snow from accumulating on roadways. Though these chemicals can have a significant positive impact on maintaining safe roadways, their chemical properties have serious negative impacts in terms of corrosion. These materials are highly soluble in water, which allows them to form a very fine mist that can penetrate deeper into gaps and void spaces in vehicles than were possible before. Such materials are also hygroscopic, which means they will absorb moisture from any available source, including the air itself. This means that even when vehicles are dry; these materials will continue to attract moisture and will continue to react with any metal surface they are in contact with (Lockridge, 2007).

Motor vehicles today are constructed with a wide variety of metals such as steel, cast iron, aluminum, magnesium, and copper alloys. All of these materials are subject to the corrosive effects of modern de-icing materials (Nazari, Shi, Bergner, Fey, 2015).

Most metallic components of modern vehicles are vulnerable to de-icing agent exposure, with key affected components being electrical wiring, frames, brackets and supports, and brake components. Knowing this, agencies should implement corrosion resistance requirements starting at the equipment selection and design stages. Other actions that can be taken to reduce the impact of chloride de-icing materials are use of chloride neutralizing agents, application of corrosion inhibitors, and de-humidification of vehicle storage areas (Shi, Li, Jungwirth, Fang, Seeley, Jackson, 2013).

NFPA 1901 Standard for Automotive Fire Apparatus (2003) establishes the design and construction standards that apparatus builders are required to comply with. There is surprisingly little in this standard that deals with corrosion prevention. The only reference found was in Chapter 15 Section 9 Metal Finish which states that "Where dissimilar metals that pose a galvanic corrosion or reactive threat are to be mounted together, the mounting base material shall have an isolation barrier prior to assembly to prevent dissimilar metal reaction (pg. 84)."

NFPA 1915 Standard for Fire Apparatus Preventive Maintenance Program (2000) does require inspection of corrosion and repairs where necessary, but has no guidelines or requirements for corrosion prevention.

The Utah Department of Transportation study on lifecycles of its snowplow fleet analyzed the contributing causes to frame failure in its vehicle fleet. The primary causal factor identified was corrosion created by de-icing materials being trapped between the frame channels on vehicles equipped with double channel frame rails. This process, also commonly referred to as "rust jacking" appeared in several other articles not specifically cited in this project. This is a very important factor for the fire service, as a double channel frame rail construction is very common across all manufacturers of fire apparatus. The UDOT report actually addresses the issue by requiring all trucks purchased after 2003 to employ a single channel frame rail design. This report concluded that vehicles with frames that had cracked were essentially considered a “total loss” due to the high repair cost compared to the value of the vehicle (Asset Management Associates PLLC, n.d.).

Corrosion impact is a wide reaching issue that affects virtually every aspect of modern life. Transportation, Utilities, Chemical, Oil and Gas, and Industry all face some degree of financial impact from corrosion. The annual cost of corrosion worldwide is estimated to exceed $1.8 trillion U.S. dollars (Schmitt, 2009).

Military organizations have invested a great deal of time and research into development of corrosion mitigation strategies. In 2002, the US Federal Highway Administration estimated the annual cost of corrosion at $276 billion dollars, with $10 to $20 billion in costs attributed to the military alone. As a result of an act of Congress in 2003, the Department of Defense designated an organization to create a long-term strategy to reduce corrosion and its effects. One of the outcomes of this process is all DoD purchases over $10,000.00 now require a corrosion control plan prior to acquisition.

The importance of dehumidification in vehicle storage areas is an area where the military is seeing positive results in managing corrosion. Keeping the storage environment at 30-40% relative humidity has been found to suppress atmospheric corrosion. This has allowed for extended service life with less downtime. Another important management tool for the military has been the application of corrosion preventive compounds (CPCs). The compounds were found to greatly reduce crevice corrosion on steel samples in test done by the Defense Science and Technology Organization (Wang and Underhill, 2006).

Based on the information found in the literature, additional information was needed in order to determine the prevalence of liquid de-icer use in Northeast Ohio. Additional information was also needed on the impact corrosion was having on fire department vehicles outside of Bath Township.

Procedures

In order to determine the significance of the use of de-icing agents, a phone poll was conducted with all street and highway maintenance departments within the BFD response area to determine if any of these agents were commonly used. The complete results of this poll are shown in Appendix B. It is important to note that while the use and type of liquid de-icing agents varied from jurisdiction to jurisdiction, the use of granular sodium chloride (rock salt) was prevalent among all agencies contacted. Given the results of the phone poll conducted regarding materials that are applied to roadways, it will be assumed that any community in an area where snow and ice is present will apply some form of snow and ice control treatments to its roadways during inclement weather.

In order to gather information that was pertinent to answering the research questions, a brief survey was sent via email to approximately 100 fire departments in northeast Ohio. A copy of the survey instrument is shown in Appendix C. The survey asked for the departments 2017 annual call volume and type of staffing in order to examine any possible relationship between frequency of equipment use and corrosion related issues. Departments were asked to identify what brands of fire vehicles were used by their departments and what their expectations were in terms of vehicle service life. The survey then asked several questions regarding types of repairs that were required over the last 3 years that were specifically related to corrosion. These questions were answered through a graded scale of less to more frequently in order to keep the survey simple and more likely to be completed. The end of the survey asked about vehicle washing frequency and any corrosion control measures that the department was currently taking. The survey concluded with an opportunity to enter any additional comments that the individual completing the survey felt were important. Approximately 70 of the 100 surveys sent out were completed.

Due to the fact that the use of snow and ice control agents was so prevalent in northeast Ohio, six departments were selected from areas of the country where these agents were not used and asked to complete the survey also. These surveys were intended to identify the significance of the link between the use of snow and ice control materials and associated corrosion problems.

No restrictions were made in regards to department run volume in an effort determine what impact, if any, overall call volume had on the frequency of corrosion related repairs.

Definition of Terms

All terminology was used in the surveys conducted was commonly associated terms within the industry. No additional definitions were required.

Limitations of the Study

This study did not look at equipment failures or repairs related to non-corrosion issues. Though corrosion issues affect all types of vehicles used in fire and emergency medical services, this study will focus only on motorized fire apparatus such as engines, ladders, tenders, etc. The study did not look at the elapsed time agencies had been utilizing any corrosion prevention programs, it was only intended to determine if there were programs in place or not.

Results

The survey that was distributed to departments in northeast Ohio received 72 responses, accounting for an approximately 70 percent completion rate. Several respondents followed up with additional information or comments via email or phone conversations with the author. The surveys that were sent to departments in regions where snow and ice control were not regularly required experienced approximately a 50 percent return rate. The information received from the surveys provided good data to assist with answering the research questions.

Research question one asked what factors could be contributing to the corrosion issues Bath FD was experiencing. Based on information found in the literature review, the phone survey of roadway maintenance departments in the Bath FD response area revealed nearly 100 percent of the area uses some form of liquid snow and ice control agent (see Appendix B for details.) The proliferation of these materials and the duration of their use directly correlates with the time period where Bath FD began to notice increased corrosion issues. Many departments reported using a commercially prepared product called Aqua-Salina which is a combination of calcium, magnesium, and potassium chlorides. This product is available with corrosion inhibitors added, but only about 50% of those using this product were paying the additional cost to have the corrosion inhibitor added.

Excessive humidity in apparatus storage areas also appears to be a contributing factor. A common practice at Bath FD is to at least rinse off the exterior of apparatus after each run during inclement weather with a more thorough washing at the beginning of each shift. This practice commonly leads to vehicles and apparatus bays being continually wet. This, combined with bays being closed up due to cold weather, creates an abnormally high humidity level in the vehicle bays. Given the hygroscopic nature of modern liquid snow and ice preventives, this practice keeps those materials activated and exhibiting their destructive corrosive properties almost continually.

Research question two was what steps could be taken to minimize corrosion issues at Bath FD. When looking at what has worked successfully in the transportation and highway maintenance arenas, proper maintenance and inspection offers the best chance of keeping corrosion under control. Regular application of a corrosion inhibitor has been very successful in preventing or at least delaying significant corrosion. Some sources also recommend removal of excess scaling and re-application of a corrosion inhibiting paint at regular intervals throughout the service life of the vehicle. Vehicle design is also an important factor. Examples can be found in literature and survey comments of instances where double rail frame construction caused premature failure due to corrosion between the two rails caused the frame to fail.

Research question three looked at what other departments were experiencing in terms of vehicle corrosion. The survey asked respondents for their departments total call volume in 2017. The data shows that call volume does not play a significant role in the frequency or extent of corrosion issues, but was a significant factor in the expected service life of the vehicle. All respondents reported some form of snow and ice control substance being used on their roadways.

Though Pierce manufacturing was the most common brand of apparatus in use, there were corrosion issues reported across all manufacturers. The data collected was not sufficient to determine if one manufacturer had a statistically better record than another as it relates to corrosion related repairs.

Apparatus manufacturers were varied as illustrated in Figure one.

Apparatus owned by departments surveyed by manufacturer

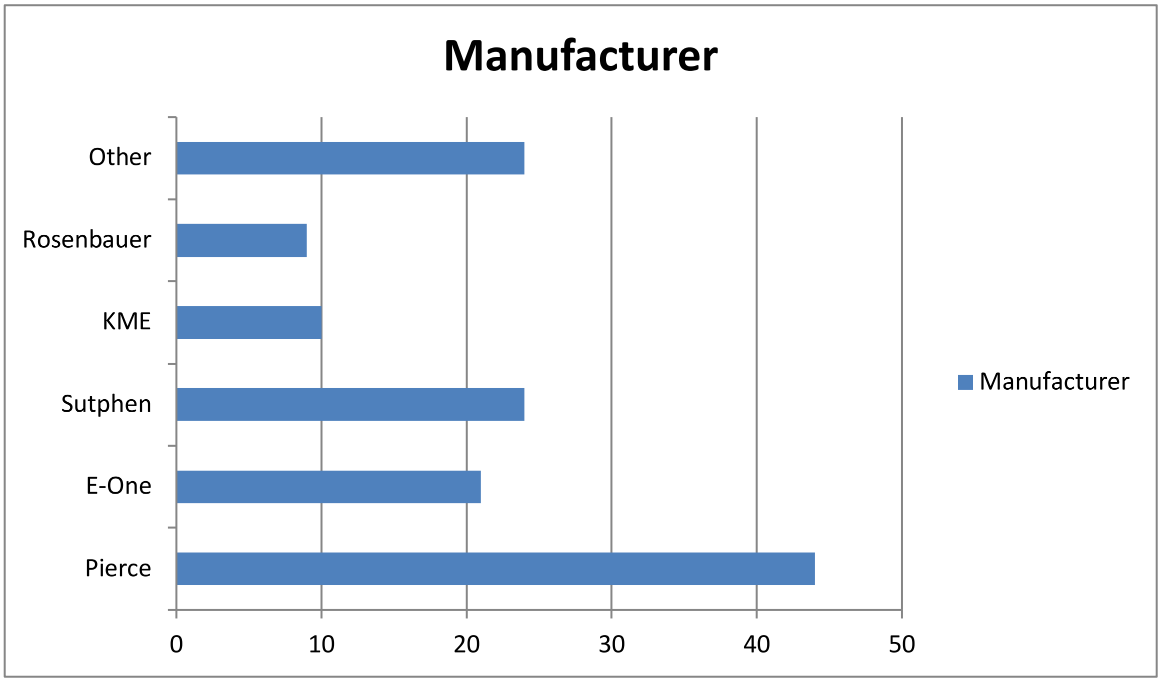

Figure 1

The types of issues most commonly encountered affected body components (exterior body panels, grab handles, door latches, etc.), electrical components, and braking components. Figure two illustrates the number of respondents that reported three or more repairs in each category in the last three years.

Frequency of repairs in fire apparatus by type of repair

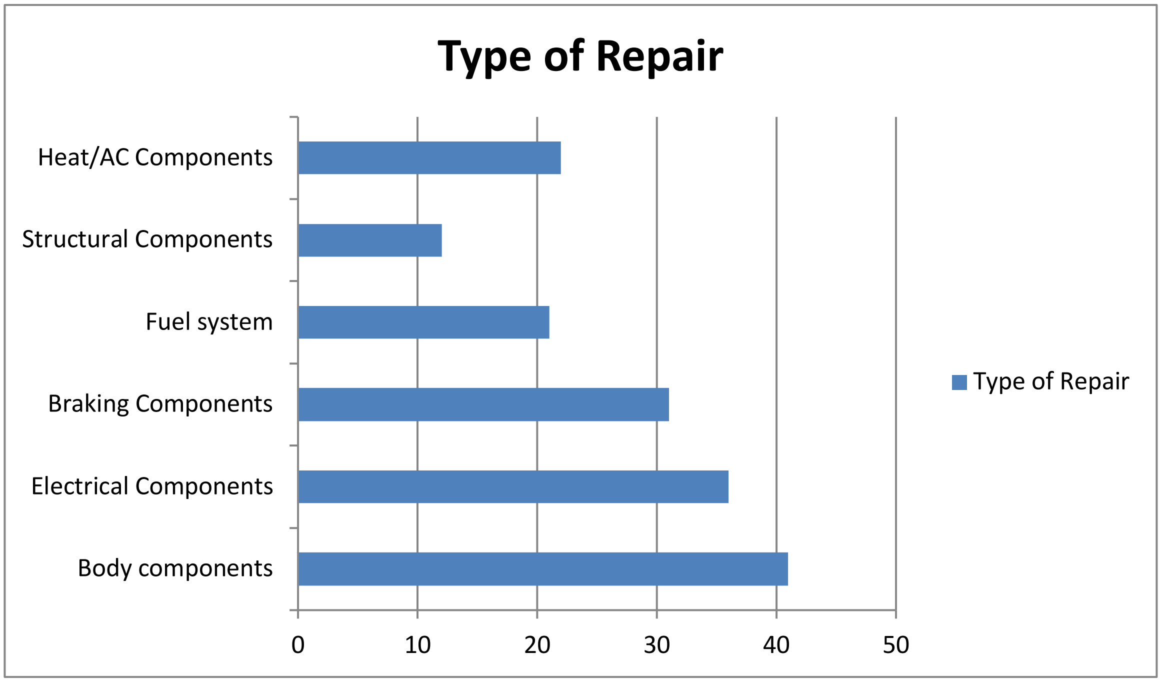

Figure 2

Though structural components had the lowest reported amount of repairs, 27.8% of respondents reported retiring a vehicle from service prior to its anticipated service life due to corrosion. An additional 8.3% reported corrosion may have played a role in prematurely retiring a vehicle from service. The departments surveyed in areas where snow and ice control materials were not routinely used had a significantly lower frequency of corrosion related repairs, and none of them reported premature retirement of apparatus due to corrosion.

Research question four was to determine what other fire departments were doing to address corrosion prevention in their vehicles. The information gathered looked at the frequency of washing the exterior surfaces of the vehicles in addition to any other preventive measures respondents had utilized.

Vehicle washing schedules were varied, with 66.7% of respondents reporting vehicles were washed daily. Only six percent of respondents reported a washing frequency less than daily. The remainder reported rinsing or washing vehicles more than once per day, at least during periods of inclement weather.

In addition to keeping vehicles washed, several other prevention measures were reported. Figure three illustrates the types of preventive measures that were reported.

Corrosion Prevention Measures by frequency

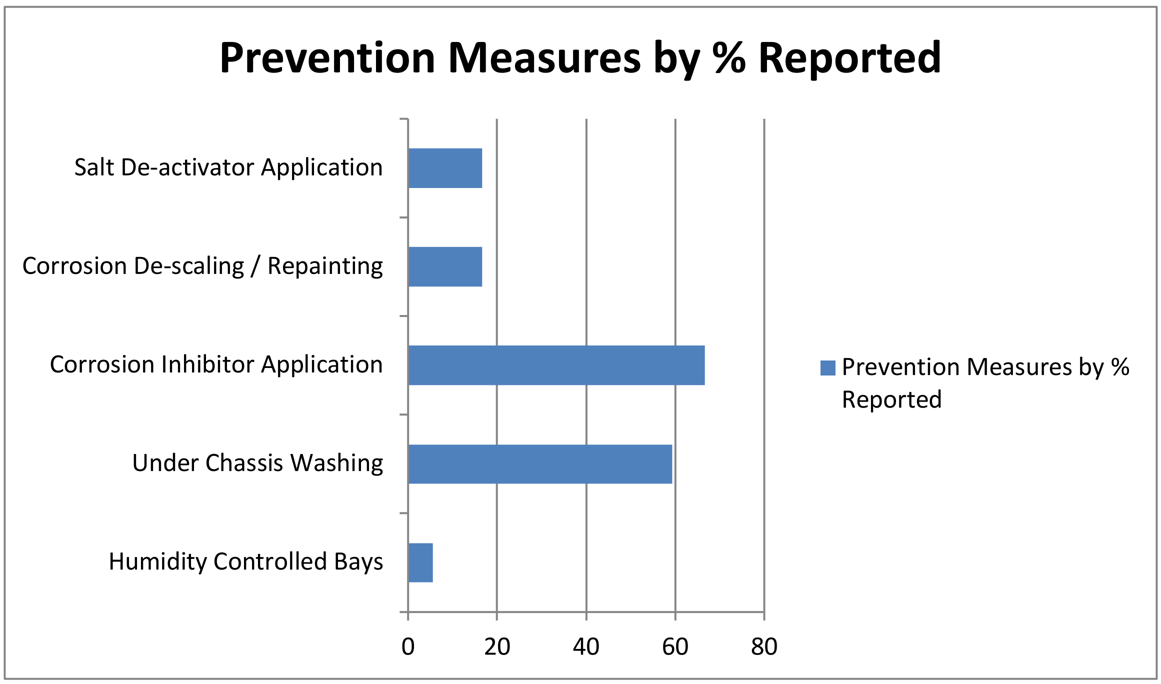

Figure 3

Periodic application of a corrosion inhibitor such as Fluid Film or Carwell was the most common prevention measure reported. Under-chassis washing was also a common prevention measure. Very few respondents reported doing anything to control the humidity level in vehicle storage areas.

The data was somewhat inconclusive in regards to how effective any prevention measures were as many departments reported both utilization of preventive measures and having to prematurely remove a vehicle from service. Several departments did note in their comments that they had seen a positive impact in reducing corrosion issues once they started applying preventive measures. Some departments also noted that a very positive effect was found when corrosion prevention measures were implemented when the vehicle was new as opposed to treating older vehicles that already had corrosion issues.

Discussion

The threat of corrosion to fire department vehicles is not an issue that will go away any time in the foreseeable future. Modern society expects roadways to be kept virtually snow and ice free at all times. Communities tasked with roadway maintenance may not have the financial resources to utilize newer products that are designed to inhibit corrosion development. The fire service needs to recognize this issue and begin to address it in a proactive manner, much as the trucking industry is doing. While elimination of all corrosion is likely never achievable, many steps can be taken to reduce the speed and extent of corrosive damage.

No areas of the country are completely immune to the effects of corrosion on their vehicles. Departments surveyed in areas where snow and ice were not a concern still reported issues related to corrosion, but the impact was much less severe than what was found in areas prone to snow and ice. Other causes such as atmospheric salt content in coastal areas and use of firefighting agents that are corrosive in nature such as foam concentrates can contribute to corrosion issues. Fire departments must look at their specific environment and identify the potential causes for corrosion development and take the appropriate steps to mitigate those risks.

The most concerning statistic found during the research phase of this project was that nearly 28 percent of the departments surveyed reported premature replacement of a vehicle due to corrosion with an additional eight percent responding that corrosion may have contributed to premature replacement. This statistic is particularly disturbing. A new fire engine/pumper can cost $350,000 to $650,000, and most new aerial ladder trucks are exceeding $1,000,000. With most departments in the United States today operating on very limited financial resources, having vehicles this costly not fulfill their intended service life cannot be tolerated.

Clearly, the most effective way to deal with corrosion is to manage it before it starts. The process of preventing corrosion must begin with vehicle design and specification (Nazari, Shi, Bergner, Fey, 2015). A common construction practice, particularly in lower cost apparatus, is the use of double rail frame construction. This method provides for greater strength by reinforcing the primary frame rails with another frame channel welded to the inside of the primary channel. This is a design feature that makes the frame exceeding susceptible to corrosive failure. Fine particulates of corrosive materials can easily migrate into the space between these rails where it cannot be effectively removed or neutralized. This area can then corrode unchecked until the decomposing materials create so much pressure that the outer frame rail fractures. This process is commonly called rust jacking (Asset Management Associates PLLC, n.d.).

Fire service vehicles should be specifically designed using only a single channel frame rail construction to eliminate this risk. In addition to frame construction, fire departments should also look at other construction factors such as use of advanced paint finishes, proper treatment of all structural penetrations, and placement of components that utilize corrosive substances such as foam systems can all help with reduction of corrosion issues. Underbody areas should be free from components that could be damaged by application of pressurized water or salt neutralizing agents. Any area where two or more different metals meet must be protected with some type of non-conductive barrier device. Utilization of single piece grab handles can eliminate issues commonly found with traditional rail and stanchion type construction which allowed for corrosion to accumulate in the joints between the two pieces and cause fractures similar to the dual channel frame construction. Fire departments must begin to put more emphasis on the design and construction of the unseen structural areas of the apparatus than the traditional focus of the more visible functional areas of the vehicle.

Constructing vehicles with a focus on corrosion reduction is an important step in the process, but it is only a first step. Ongoing inspection and maintenance is what will have the most significant effect on reducing the devastating effect of corrosion. The fire service is well known for keeping the vehicle exterior clean and looking sharp. This same attention must start to be applied to the unseen areas of the vehicle as well. Thorough rinsing of the vehicle undercarriage and drivetrain should be performed regularly when vehicles are subjected to corrosive environments such as roadways with snow and ice removal materials applied. Vehicles should receive at least an annual corrosion inspection. Use of chloride neutralizing agents and application of some form of corrosion inhibitor would also be beneficial (Shi, Li, Jungwirth, Fang, Seeley, Jackson, 2013). Areas that have extensive corrosion need to be addressed by removing the deteriorated material and repainting the damaged area with a corrosion inhibiting finish such as POR-15 or equivalent.

The environment that vehicles are stored in is also a significant factor. Corrosion rates can be significantly affected by increased humidity and temperatures. Fire apparatus must be kept in enclosed, heated areas especially during periods of extreme cold temperatures. This creates an increased potential for high levels of humidity, which increases the corrosive effect of chloride de-icers. Fire Departments should strive to monitor and keep humidity levels in the 30 to 40 percent range in all vehicle storage areas (Wang and Underhill, 2006).

Recommendations

The purpose of this research was to determine what potential causes exist for the increased corrosion issues Bath FD was experiencing and to identify potential ways to stop or minimize the development of corrosion. The literature reviewed and survey of area highway maintenance agencies affirms that chloride based chemical de-icers are a significant factor for Bath FD. Based upon reviewed literature and research-based survey questions, the following recommendations are being made:

The first recommendation is to require future fire department vehicle purchases to be designed with corrosion resistance and prevention in mind. Vehicles should be specified to have only single channel frame rails. Areas where metal joints overlap should be individually primed and painted prior to assembly. All frame and underbody components should be primed and painted with corrosion inhibiting finishes. Overlapping joints between metal surfaces should be limited as much as possible. Items such as body grab rails should be a single piece design. Door panels should provide easy access to latch assemblies for cleaning and lubrication.

The second recommendation is to limit vehicle washing to once per day, and only for vehicles that are in need of washing. When vehicles are washed, they must be dried and all excess water removed from the vehicle storage areas. Limiting the amount of time vehicles are wet will reduce moisture accumulation within the storage areas and thus slow the corrosive properties of any de-icing materials present. Equipment for washing the underside of the vehicles should be purchased, and a regular under chassis washing schedule should be developed.

The third recommendation is to begin monitoring relative humidity levels in all vehicle storage areas. Air handling systems that are capable of maintaining a relative humidity level of 30-40% in vehicle storage areas should be investigated and budgeted for future improvements. This recommendation is likely the most expensive to implement, and will take some time to accomplish. Some short term options for managing humidity are use of fans to circulate air around the vehicles better, opening of doors and windows when temperatures moderate to improve airflow, and use of prepared desiccant products that can remove at least some of the moisture from the air.

All of the above recommendations have been implemented in a written corrosion control policy. A sample policy is shown in Appendix D. Having these items written in policy form allows for consistent application over time. It also allows for periodic revision as additional research or new products become available.

Though the research that was conducted has provided some valuable information to assist Bath FD with preserving its vehicle fleet, it is clear the fire service needs to do significantly more research on this issue. Research of vehicle construction methods, performance of chloride neutralizing agents and corrosion inhibitors, and advanced paint finishes are all areas where there is much to be learned. Partnerships with the trucking and highway maintenance industries should be pursued industry wide to share information and develop best practices for managing the corrosion threat.

In addition to further research, the fire service must also begin to be a leading voice in lobbying state and local governments to demand more from the suppliers of their snow and ice treatment materials. The use of chemical de-icing products is only likely to expand in the future, therefore manufacturers must make corrosion inhibition an integral part of these products. Though this may create additional cost to purchase de-icing products, the savings created by reduced corrosion damage and premature retirement of vehicles would likely cover a substantial amount of the added cost.

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Appendix A: Responses and Mileage per Year by Unit

Responses per Year by Unit

Unit	2015	2016	2017
Engine 14	243	350	205
Engine 15	122	28	166
Tanker 18	25	13	20
Medic 11	317	537	481
Medic 12	394	169	201
Medic 21	433	408	446

Mileage per Year by Unit

Unit	2015	2016	2017
Engine 14	N/A	N/A	1,956
Engine 15	1,792	841	1,787
Engine 24*	2,992	3,162	1,685
Tanker 18	619	642	656
Medic 11	6,597	10,504	8,997
Medic 12	7,270	4,971	5,667
Medic 21	15,487	18,029	16,530

*Engine 24 previously assigned as Engine 14 prior to receiving new engine in 2017

Appendix B: Roadway Snow and Ice Control Materials

Jurisdiction	Contact	Salt Brine	Calcium Chloride	Magnesium Chloride	Pottasium Chloride	Agricultural Product
Bath Township	Caine Collins		Since 2017**	Since 2017**	Since 2017**	2016
Copley Township	Mark Mitchell			Used in 2013 and 2018*		
City of Fairlawn	Linda Algie		10+years			
Village of Richfield	Steve Lisowski		Last used 1990s			20+ years
Summit County	Patrick Dobbins	20+years	20+Years	2018**	2018**	
State of Ohio	Brian Olsen	Since 2000	30+ Years	3 years**	3 years**	18 years

***Brand name ClearLane- Sodium Chloride/Magnesium Chloride blend**

**** Brand Name Aqua Salina- Potassium, Magnesium, and Calcium Chloride blend**

Salt Brine- 23% sodium chloride / 77% water solution

Agricultural Product- agricultural byproducts such as beet juice

Appendix C: Survey Instrument

Vehicle Corrosion Survey

The following short survey is intended to assist with gathering research data regarding the extent of
corrosion related issues in fire department fleets.

1. **What was your 2017 Annual Call Volume?**

2. **How is your department Staffed?**

Mark only one oval.

All Full-Time Personnel
Combination Full and Part-Time Personnel
All Part-Time Personnel
All Volunteer Personnel
Other:

3. **What brand of vehicles do you have in your department (Pick all that apply)**

Check all that apply.

Pierce
E-One
Sutphen
Rosenbauer
KME
Seagrave
Other:

4. **What is the typical service life of your fire apparatus?**

Mark only one oval.

0-5 years
6-10 years
11-15 years
16-20 years
21-25 years
25+ years

5. **Does your department routinely operate in areas where snow and ice control products are applied to roadways in the winter?**

Mark only one oval.

Yes
No
Maybe

6. **Have you ever had to retire a vehicle from service prior to its anticipated service life due to corrosion issues?**

Mark only one oval.

Yes
No
Maybe

7. **Has your department had to make any electrical system repairs (lights, wiring, control modules, etc.) due to corrosion in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

8. **Has your department had to make any braking system repairs (pads/shoes, drums/rotors, air tanks, brake chambers, etc.) due to corrosion in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

9. **Has your department had to make any fuel system repairs (fuel tanks/straps, fuel lines) due to corrosion in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

10. **Has your department had to make any pump or plumbing repairs due to to corrosion in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

11. **Has your department had to make any heating/air conditioning system repairs due to corrosion in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

12. **Has your department had to make any body repairs (includes door latches, grab handles, etc.) due to corrosion in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

13. **Has your department had to make any structural repairs (frame/subframe components, aerial ladder or torque box, etc.) in the last 3 years?**

Mark only one oval.

1 2 3 4 5

1=Never 5=Frequently (5 or more)

14. **How frequently does your department wash vehicles**

Mark only one oval.

After Every Run
Daily
Weekly
Other:

15. **Does your department do any of the following corrosion prevention measures? (Pick all that apply)**

Check all that apply.

Humidity controlled storage bays
Under Chassis washing
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Descaling/ Repainting
Salt de-activator application

16. **Additional Comments**

Vehicle Corrosion Survey.pdf

Appendix D: Sample Corrosion Control Policy

BATH FIRE DEPARTMENT

Subject: **Vehicle Corrosion Control**	
	Effective Date: **DRAFT**
	Revision Date:

Introduction:

Modern fire department vehicles can be very costly to obtain. These vehicles are expected to provide reliable service for up to 20-25 years depending on the type of vehicle. Exposure of these vehicles to corrosive environments such as winter snow and ice removal products, and corrosive firefighting agents such as foam concentrates can cause extensive damage up to and including premature mechanical failure and retirement of a vehicle. Proper design, care, and maintenance are the best defenses against corrosion related damage and repairs.

Objective:

Top provide a standardized approach to vehicle construction and maintenance in order to reduce or prevent corrosion damage to fire department vehicles.

Vehicle design and Construction:

New department vehicles should be specified to use a single channel frame rail system. Double or lined rails are much more prone to corrosion in concealed, inaccessible areas and their use should not be allowed.

Any metal joints that overlap must be individually primed and painted using corrosion inhibiting finishes prior to assembly.

Exterior grab handles should be of a single piece, mandrel bent design. Overlapping metal extrusions with end stanchions should not be allowed to be specified.

All underbody components should be protected with corrosion inhibiting primers and paints. Any modifications or penetrations of the underbody components must be cleaned, primed and painted. There should be no exposed raw metal anywhere on the vehicle.

Any areas where foam concentrate or other corrosive materials could come into contact with metal surfaces should have a non-corrosive barrier to prevent contact.

Cab and compartment doors should have easy access to any latching mechanisms to allow for cleaning and lubrication.

Any areas where dissimilar metals meet must have a non-conducting barrier separating the different metals.

Vehicle Care and Washing

Vehicle exteriors should be washed as needed once per day at the beginning of each shift. Giving vehicles a "courtesy rinse" after calls is not permitted. If a vehicle is in need of cleaning, it must be washed with soap and water and thoroughly dried. After washing, remove all excess water from the bay floors and turn on the ventilation fans in the bays to dry everything out as much as possible.

During winter weather events, CRC Salt Terminator should be applied to the underside of the chassis whenever the vehicle is washed.

Vehicles should receive a complete underbody cleaning each spring and again each fall prior to inspection and corrosion inhibitor application.

All vehicles should be thoroughly detailed and waxed at least annually.

Preventive Maintenance and Inspection

All door latches and hinges should be cleaned and lubricated monthly by the fire department maintenance staff.

Each year between October 1 and November 30, each vehicle will be completely inspected for corrosion damage. Vehicles will be lifted so that a thorough inspection of the underside of the vehicle can be completed.

Any areas of significant corrosion where the metal has started to deteriorate will be appropriately descaled and repainted with a corrosion inhibiting product such as POR-15 or equivalent by a qualified body shop.

Once significant corrosion areas are repaired, the entire underbody area will be treated with a corrosion inhibitor such as Fluid Film or equivalent by the fire department maintenance staff.

Upon completion of inspection and treatment, a maintenance report shall be entered into the vehicles maintenance record that is to include the findings of the inspection and what actions were taken for treatment.

Appendix E: Raw Survey Data

Survey Question 1	Survey Question 2
1492	Combination Full and Part-Time Personnel
1650	Combination Full and Part-Time Personnel
915	Combination Full and Part-Time Personnel
2500	All Full-Time Personnel
	All Full-Time Personnel
	Combination Full and Part-Time Personnel
3200	All Full-Time Personnel
	Combination Full and Part-Time Personnel
	Combination Full and Part-Time Personnel
725	All Part-Time Personnel
	All Full-Time Personnel
2200	Combination Full and Part-Time Personnel
3783	All Full-Time Personnel
2000	Combination Full and Part-Time Personnel
6,424	All Full-Time Personnel
2729	Combination Full and Part-Time Personnel
5175	All Full-Time Personnel
3691	All Full-Time Personnel
5880	All Full-Time Personnel
2137	Combination Full and Part-Time Personnel
5200	All Full-Time Personnel
1961	Combination Full and Part-Time Personnel
1500	Combination Full and Part-Time Personnel
3350	All Full-Time Personnel
1408	All Part-Time Personnel
4353	All Full-Time Personnel
6500	All Full-Time Personnel
	All Full-Time Personnel
510	All Part-Time Personnel
1347	All Part-Time Personnel
	Combination Full and Part-Time Personnel
3400	All Full-Time Personnel
6600	Combination Full and Part-Time Personnel
1,820	Combination Full and Part-Time Personnel
3200	All Full-Time Personnel
1600	Combination Full and Part-Time Personnel
904	Combination Full and Part-Time Personnel
8553	All Full-Time Personnel
5700	All Full-Time Personnel
3209	All Full-Time Personnel
4422	All Full-Time Personnel
2549	Combination Full and Part-Time Personnel
10,824	All Full-Time Personnel
1551	Combination Full and Part-Time Personnel
	Combination Full and Part-Time Personnel
1350	Combination Full and Part-Time Personnel
160 calls	All Volunteer Personnel
6600	Combination Full and Part-Time Personnel
126	Combination Full and Part-Time Personnel
Newburgh Heights Fire Dept. - 489 for	Fire Chief is Full Time - All other members are Part-Time - (2) FF's 24/7
2700	All Full-Time Personnel
2406	All Full-Time Personnel
600	All Part-Time Personnel
1500	Combination Full and Part-Time Personnel
	Combination Full and Part-Time Personnel
490	All Part-Time Personnel
2800	Combination Full and Part-Time Personnel
725	All Part-Time Personnel
600	Paid-On-Call
304	All Volunteer Personnel
600	All Part-Time Personnel
1976	Combination Full and Part-Time Personnel
3841	All Full-Time Personnel
4200	All Full-Time Personnel

2733	All Full-Time Personnel
2,369	Combination Full and Part-Time Personnel
2500	Combination Full and Part-Time Personnel
750	All Part-Time Personnel
3000	All Full-Time Personnel
106	All Full-Time Personnel
4086	All Full-Time Personnel
7350	All Full-Time Personnel

Survey Question #3 (Pick all that apply)	**Survey Question #4**	**Survey Question #5**
Pierce, Sutphen, Rosenbauer	16-20 years	Yes
Sutphen, Horton	6-10 years	Yes
Ford	11-15 years	Yes
Pierce, Sutphen, Ford, Chevy	16-20 years	Yes
Pierce, E-One, Sutphen	16-20 years	Yes
	16-20 years	Yes
E-One, Rosenbauer	16-20 years	Yes
E-One, Sutphen, Lifeline	25+ years	Yes
Pierce, E-One	21-25 years	Yes
Pierce, 4-guys	21-25 years	Yes
Pierce, Sutphen, KME	16-20 years	Yes
Pierce	16-20 years	Yes
Pierce, E-One, Ferrara	16-20 years	Yes
Pierce, Sutphen	25+ years	Yes
Sutphen, American LaFrance	16-20 years	Yes
Pierce, Fourguys, Braun, Lifeline, Ford	21-25 years	Yes
Pierce, E-One	11-15 years	Yes
Pierce, E-One	11-15 years	Yes
Pierce	16-20 years	Yes
E-One, Rosenbauer	21-25 years	Yes
Pierce, Sutphen	16-20 years	Yes
Pierce, E-One	21-25 years	Yes
Pierce, Smeal	16-20 years	Yes
E-One	21-25 years	Yes
Rosenbauer, KME	21-25 years	Yes
Pierce, Seagrave	21-25 years	Yes
E-One, Rosenbauer, Horton	11-15 years	Yes
Sutphen, Ferrara	16-20 years	Yes
Pierce	21-25 years	Yes
Pierce	25+ years	Yes
Pierce	21-25 years	Yes
Pierce	16-20 years	Yes
Sutphen, American La France	11-15 years	Yes
E-One	25+ years	Yes
Pierce, Sutphen, American LaFrance	21-25 years	Yes
Sutphen	25+ years	Yes
Pierce, KME	21-25 years	Yes
Pierce	16-20 years	Yes
Sutphen, Ferrara	21-25 years	Yes
E-One	21-25 years	Yes
Pierce, Sutphen, Seagrave	25+ years	Yes
Pierce, KME	25+ years	Yes
Sutphen, KME, Ford E-450 (3)	11-15 years	Yes
Pierce, E-One	16-20 years	Yes
Pierce, Sutphen	25+ years	Yes
Pierce, Sutphen, 4-Guys	21-25 years	Yes
E-One, KME	16-20 years	Yes
E-One, Sutphen, American LaFrance	16-20 years	Yes
KME	25+ years	Yes
Pierce	6-10 years	Yes
Pierce, E-One	21-25 years	Yes
Pierce	21-25 years	Yes
Pierce	11-15 years	Yes
E-One	21-25 years	Yes
Pierce, Sutphen	16-20 years	Yes
Rosenbauer, KME	21-25 years	Yes

E-One, Ferra	21-25 years	Yes
Quality, Ferrara and Percision	21-25 years	Yes
Pierce	16-20 years	Yes
Pierce, Sutphen	16-20 years	Yes
KME, 4 guys, S&S	25+ years	Yes
Pierce, Sutphen, KME	16-20 years	Yes
Pierce	16-20 years	Yes
Pierce	11-15 years	Yes
Pierce, Sutphen	25+ years	Yes
Pierce, Rosenbauer	16-20 years	Yes
Sutphen, Osage	16-20 years	Yes
Pierce	21-25 years	Yes
E-One, Rosenbauer	16-20 years	Yes
Pierce, Seagrave, Ford, Chevy ambulances, sedans, chief SUVs and Wildland trucks	6-10 years	Maybe
Pierce, E-One, Rosenbauer	21-25 years	Yes
Spartan / Crimson	11-15 years	No

Survey Question #6	Survey Question #7	Survey Question #8	Survey Question #9	Survey Question #10	Survey Question #11
Yes	4	3	2	2	3
No	3	3	2	2	2
No	2	1	1	1	1
Yes	4	2	2	4	2
No	3	3	3	1	1
No	4	2	1	3	1
Yes	4	4	5	1	4
No	3	3	3	4	3
No	4	2	2	2	1
No	2	1	1	1	1
No	3	4	3	5	4
No	3	2	1	2	1
No	3	1	2	3	2
No					
Yes	5	5	5	5	4
No	2	2	2	2	1
Maybe	5	4	3	3	3
No	5	5	5	3	5
Yes	4	4	4	4	4
No	4	4	4	2	2
Yes	5	5	5	5	5
No	3	2		2	
Yes	5	4	4	2	2
No	4	4	1	1	4
No	3	1	1	1	1
Yes	4	3	4		2
Yes	4	4	4	2	3
No	2	2	1	1	1
Yes	2	4	3	3	4
No	3	1	1	1	1
No	4	4	2	3	4
Yes	3	4	4	4	2
Yes	3	4	3	3	4
No	3	2	1	3	4
Maybe	3	3	5	1	4
No	5	4	2	1	4
No	4	3	3	2	1
No	2	2	2	3	2
No	5	5	2	5	2
Yes	4	4	4	2	4
No	2	2	2	1	1
No	4	2	1	2	1
No	5	5	5	5	5
No	3	3	2	2	5
No	2	4	2	2	2
Yes	3	3	3	3	3
Maybe	5	5	5	2	1
No	4	4	2	2	2

No	1	1	1	1	1
No	1	1	1	2	1
No	2	2		1	1
No	2	2	2	2	2
No	4	3	1	3	1
Yes	5	4	4	5	4
No	3	3	2	1	1
No	2	2	1	1	2
No	4	4	4	3	2
No	4	4	4	2	2
No	2	2	1	2	1
Maybe	4	2	5	4	2
Maybe	5	5	5	5	5
No	4	4	2	3	3
Yes	5	5	2	2	4
Maybe	5	4	4	3	3
No	2	2	3	2	2
Yes	5	3	2	4	4
No	3	1	1	1	1
Yes	3	1	1	4	1
Yes	5	3	3	3	4
No	1	1		1	2
No	4	4	4	3	2
Yes	2	4	4	1	4

Survey Question #12	Survey Question #13	Survey Question #14
5	3	Daily
2	1	Daily
5	1	Daily
4	2	Daily
4	1	Weekly
2	1	Daily
5	2	Daily with a rinse after calls during the winter months
3	3	Daily
5	3	Daily
3	1	after every run in winter, as needed in summer
4	2	Daily
3	3	Daily
5	1	Daily
		After Every Run
5	4	Daily
4	1	Daily
4	4	Daily
5	4	Daily
4	4	Daily
3	1	Daily
5	5	rinsed after run if warranted
4	5	Daily
3	1	Daily
5	5	Daily
1	1	Daily
3	2	Daily
4	4	Daily
2	1	Daily
5	1	After Every Run
1	1	Weekly
5	5	Daily
5	1	Daily
3	2	Daily
4	1	Daily
5	5	Daily
3	2	Daily
5	4	Daily. After every run in the winter
3	3	Daily
5	3	wash daily and rinse after runs in inclement weather
5	2	Daily

2	1	Daily
3	3	Weekly
5	2	Daily
4	1	After Every Run
4	3	Daily
3	1	Daily
4	3	After Every Run
4	3	Daily
2	1	Weekly
1	1	Daily - When temperature is below 20 degrees outside we wait until truck warms up to bay temperature
1	2	After Every Run
2	2	Daily
3	1	After Every Run
4	2	Daily
3	1	Daily
3	1	Daily
4	3	Daily
4	2	Daily
1	1	Daily
4	3	After Every Run
5	5	After Every Run
4	1	Daily
4	2	Daily
	3	After Every Run
3	1	after every run during winter sloppy weather/as needed
4		Daily
1	1	After Every Run
1	1	After Every Run
5	2	Daily
1	1	Usually on each first day of our 48 hrs on 96 hours off schedule
5	1	Daily
5	1	Weekly

Survey Question #15 (Pick all that apply)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Salt de-activator application
Under Chassis washing
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Salt de-activator application
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Descaling/ Repainting, Salt de-activator application
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Descaling/ Repainting
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Descaling/ Repainting, Salt de-activator application
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing
Descaling/ Repainting
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Descaling/ Repainting, Salt de-activator application
Under Chassis washing, Salt de-activator application
Under Chassis washing
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Humidity controlled storage bays
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Salt de-activator application
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)

Under Chassis washing
Under Chassis washing
Humidity controlled storage bays
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing
Descaling/ Repainting
Under Chassis washing, Descaling/ Repainting
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Humidity controlled storage bays, Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Descaling/ Repainting, Salt de-activator application
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing
Under Chassis washing
Under Chassis washing
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Under Chassis washing, Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.), Salt de-activator application
Under Chassis washing
Under Chassis washing
Corrosion inhibitor application (Carwell, Fluid Film, oil spray, etc.)
Descaling/ Repainting